MODIS Semi-annual Report (July 1998 - December 1998)

Bo-Cai Gao, Warren Wiscombe, Wei Han, Allen Chu,
Rong Rong Li, and William R. Ridgway

(This reports covers the MODIS **cirrus characterization and correction** algorithm and part of the MODIS **near-IR water vapor algorithm**)

<u>Main topics addressed in this time period:</u>

1. **MODIS near-IR water vapor algorithm**:

Science algorithm: The combined V2 near-IR water vapor and aerosol algorithm was delivered to the MODIS Project in mid-November of 1997. The science part of the algorithm was in good shape, and no major change has been made since the code delivery. Allen Chu and Wei Han have been interacting with MODIS SDST, to make changes so that the delivered software is working on newer operating systems and with the updated tool kits. Additional metadata and QA parameters have been implemented to the near-IR water vapor algorithm. The required "operator actions" have also been implemented. An updated version of ATBD for the near-IR water vapor algorithm has been submitted to the MODIS Project Office.

Minor problems are still present in the aerosol correction module of the near-IR water vapor algorithm. One problem is that the aerosol correction module uses quite a bit of computer memory. Improvement in the coding is needed to reduce the size of the required memory. Another problem is that, when the same code was run on a DEC computer and an SGI computer, the results are slightly different over small portions of test images. The source of the error has not been positively identified yet. We will work on correcting these problems soon. In view of the minor improvements in the retrieved water vapor values by using the aerosol correction module, the processing speed, and the problems with correction module, Richard Hucek and Allen Chu have decided not to use the aerosol correction module in the present implementation of the joint MODIS aerosol and water vapor algorithm. Soon after we identify and correct the problems, the aerosol correction module can be quickly incorporated into the joint algorithm.

Validation: We plan to use water vapor measurements from microwave radiometers, radiosondes, GPS network, and AERONET to verify water vapor values retrieved from MODIS near-IR water vapor channels.

Gao and Ridgway have obtained large volumes of microwave radiometer data from the DOE ARMS' data archives. We have found that seasonal variations of column water vapor values in microwave radiometer measurements are obviously seen. Quality control of the data set is still an issue. For example, column water vapor amounts greater than 15 cm or below zero are present in the data set. These problems may be associated with rain and drizzle. We will compare the MODIS water vapor image with the time series of microwave radiometer measurements.

We plan to compare nearly coincident water vapor measurements from MODIS data and from radiosondes released from weather stations. We have identified about 300 such weather stations around the world. We are investigating how to get the radiosonde data from these stations in digital forms.

We would like to compare MODIS near-IR water vapor images with those obtained from the Japanese Global Positioning System / Meteorological Project (GPS / MET). Japan has deployed a GPS array and currently operates at about 1000 stations with a mean separation of about 15 - 30 km. We have sent e-mails to relevant Japanese scientists about our interests in getting water vapor images from the Japanese GPS array. However, we haven't received any responses from Japanese scientists so far. MODIS Project managers may be able to help if they talk with their Japanese counterparts concerning our interests in getting GPS water vapor images.

2. **MODIS thin cirrus and contrail algorithm**:

Science algorithm: The science algorithm includes two parts: thin cirrus reflectance and contrail detection. The V2 algorithm was delivered to MODIS SDST in early December of 1997. Because the design and interface have been changed at MODIS SDST, quite a bit of modifications to our code have to be made. Wei Han had been interacting with MODIS SDST regarding the algorithm, and making necessary changes. Wei added "operator actions" in all error messages for MODIS cirrus detection / correction algorithm (MOD_PR06CD) and re-delivered the code to SDST.

Since the code delivery, additional progress has also been made in the science algorithm development. The delivered at-launch version of cirrus reflectance algorithm is simple and fully functional. However, the 1.375-μm transmittance factor for water vapor above and within cirrus clouds were estimated based on latitudes and longitudes. The key in our algorithm for retrieving cirrus reflectance in the 0.4 - 1.0 μm spectral region is to accurately estimate the 1.375-μm water vapor transmittance factor. We have developed an operational algorithm to make such estimation from imaging data themselves. The transmittance factor is derived from the scatter diagram of 1.375-μm channel vs 1.24-μm channel for ocean pixels, and from the scatter plot of 1.375-μm vs 0.66-μm channel for land pixels. The quick sort subroutine in Numerical Recipes is used several times during the derivation. The algorithm has been tested using spectral imaging data acquired with the NASA JPL AVIRIS instrument. We are currently incorporating this algorithm to the first "post launch" version of MODIS cirrus reflectance algorithm.

The delivered at-launch version of the aircraft contrail detection algorithm is functional. The algorithm produces a "contrail mask" image from the 1.38 micron brightness image. Additional refinement to the algorithm has been made by Ridgway since the code delivery. We were advised not to pursue contrail related issues because contrail cirrus would not have big effects on climate - the conclusion reached by Toon based on the analysis of SUCCESS data and AVHRR and GOES imaging data. Since the MODIS 1.375-µm channel would detect more thin cirrus clouds and the detection of contrails from 1.375-µm images is relatively easy in comparison with contrail detection from AVHRR images, we have decided not to abandon our contrail related research at present. By simply looking at the sky of Washington, DC area, one can easily find that the sky is often filled by contrail cirrus. The contrail cirrus must have important regional climatic effects.

Validation: The development of cirrus reflectance and contrail detection algorithms has always been guided by real imaging data. In the case of developing cirrus reflectance algorithm, AVIRIS data acquired during NASA FIRE Phase II Cirrus experiment in December of 1991 and a few other field programs were used. In the case of developing the contrail detection algorithm, images acquired with MAS (AVIRIS does not have sufficiently large area coverage), SeaWifs, GOES, and a ground-based upward-looking digital camera, have been used.

Using pairs of spectral imaging data with and nearly without thin cirrus contamination and acquired with the AVIRIS instrument, we have found that the estimates of NDVI values can be improved quantitatively after the removal of thin cirrus effects.

3. Meeting

Ridgway and Gao participated the Atmospheric Group meeting held in St. Michaels, MD in November of 1998. Gao described the recent development of cirrus reflectance algorithm and gave examples of improving NDVI estimates by correcting thin cirrus effects. Ridgway described the contrail algorithm.. Chu described his application of the algorithm for water vapor retrievals from MAS data.

Gao, Ridgway, and Ping Yang (from UCLA) participated the MODIS Science Team meeting held in December of 1998. Gao gave a presentation on improving NDVI estimation after thin cirrus scattering effects are removed. Ping Yang had sufficient time to talk with Brian Baum and Peter Soulen on the required ice particle phase function calculations for building lookup tables to be used in the MODIS cloud optical depth algorithm.

Gao and Ridgway participated the special Cirrus conference held in Baltimore in October of 1998. The conference was organized by Optical Society of American. Both Gao and Ridgway gave presentations during the conference.

4. Publications

Gao, Bo-Cai, Y. J. Kaufman, W. Han, and W. J. Wiscombe, Correction of thin cirrus path radiances in the 0.4-1.0 µm spectral region using the sensitive 1.375 µm cirrus detecting channel, J. Geophys. Res., 103, 32,169 - 32,176, 1998.

Gao, Bo-Cai, W. Han, S.-C. Tsay, and N. F. Larsen, Cloud detection over arctic region using airborne imaging spectrometer data during the daytime, *J. Appl. Meteorol.*, 37, 1421-1429, 1998.

Wald, A., Y. J. Kaufman, D. Tanre, and B.-C. Gao, Daytime and nighttime detection of mineral dust over desert using infrared spectral contrast, *J. Geophys*. Res., 103, 32307-32313, 1998.

Gao, B.-C., Y. J. Kaufman, W. Han, and W. J. Wiscombe, Development of an operational algorithm for removing thin cirrus effects in the 0.4-1.0 µm spectral region from MODIS data using the strong water vapor band at 1.375 µm, in *Cirrus, Technical Digest*t published *by Optical Society of America*, 14-16, 1998.

Ridgway, W. L., and B.-C. Gao, Automated contrail detection using the Moderate Resolution Imaging Spectrometer (MODIS), in *Cirrus, Technical Digest*t published *by Optical Society of America*, 125-127, 1998